Marine Environmental Research 21 (1987) 75–94

The Effects of Beach Replenishment on the Benthos of a Sub-tropical Florida Beach

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(Received 24 August 1985, revised version received 16 March 1986, accepted 20 May 1986)

ABSTRACT

Changes in the benthic fauna of the near-shore zone were examined before and after a beach replenishment project on the central Florida east coast. Results indicated that the near-shore sand beach community is relatively species rich, although abundance is dominated by only two species of bivalves, the coquina clams Donax variabilis *and* Donax parvula. *Strong gradients of increased species richness and abundance were found, with values increasing at the more seaward sites for both control and nourishment locations. This distributional pattern was unchanged by beach nourishment. Comparison of mean number of individuals per core across dates and among transects (two-way analysis of variance) showed no indication of significant negative effects of beach nourishment. Similar analysis for mean number of species per core also failed to show significant negative effects. Negative biological effects of beach nourishment may have been minimized in the present case due to a seasonal offshore movement of the dominant coquina clams. The close match of mean fill grain size to ambient grain size and an apparent lack of substantial fill movement into the biologically more diverse offshore areas may also have diminished biological damage.*

INTRODUCTION

Many of the beaches along the east coast of Florida are classified as eroded (Campbell *et al.*, 1980). Of the many techniques designed to counteract

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shoreline erosion, beach nourishment, the process of adding sand to beaches, has emerged as a common method because the final result is a wide beach which is aesthetic and because the procedure does not interfere with natural, physical beach processes (Walton, 1977).

Prompted in part by concern over the biological effects of beach nourishment, general knowledge of the benthic communities of the nearshore zone of sand beaches is increasing (Dexter, 1969, 1972, 1979; Reidl & McMahan, 1974; Saloman, 1976; Matta, 1977; McLachlan, 1977; Saloman & Naughton, 1978; Spring, 1981; Leber, 1982a, 1982b; Knott *et al.*, 1983; McLachlan & Erasmus, 1983). However, relatively few studies are available which effectively detail the biological consequences of deposition and redistribution of large volumes of sand in the nearshore zone. Of studies of beach nourishment effects (Courtenay *et al.*, 1974; Parr *et al.*, 1978; Marsh *et al.*, 1980; Culter & Mahadevan, 1982; Saloman *et al.*, 1982; Reilly & Bellis, 1983), only those of Parr *et al.* (1978) and Reilly & Bellis (1983) provide information on the short-term effects of beach nourishment on benthic assemblages based on comparisons of communities before and after disturbance.

As a result of severe erosion which threatened seaside structures along the beaches of the towns of Indialantic and Melbourne Beach, Florida, a beach nourishment project was carried out between November 1980 and February 1981 (Gorzelany, 1983). During the project, an estimated 413 000 cubic meters of sand was trucked from an on-land dredge spoil site located at Port Canaveral, Florida and dumped and graded along a 3·4 km stretch of beach (Stauble *et al.*, 1983).

In this report, we quantify the benthic fauna present intertidally and subtidally along this stretch of beach preceding and following nourishment activities. Changes which took place in the benthic fauna over the approximately one year period following the initiation of the nourishment project are evaluated in an attempt to distinguish between natural variability and effects attributable to the beach nourishment.

MATERIALS AND METHODS

The nourishment project was carried out on a 3·4 km section of beach located in the towns of Indialantic and Melbourne Beach, Brevard County, Florida (Fig. 1). This high-energy beach (Tanner, 1960) is a part of the barrier island system along the Florida east coast. Intertidal grain size was 1·7 diameter with a moderate sorting of 0·74 diameter. Subtidal mean grain size was 2·75 diameter with a moderate sorting of 0·86 diameter. Details of the geological aspects of this beach system have been described by Stauble *et al.* (1983).

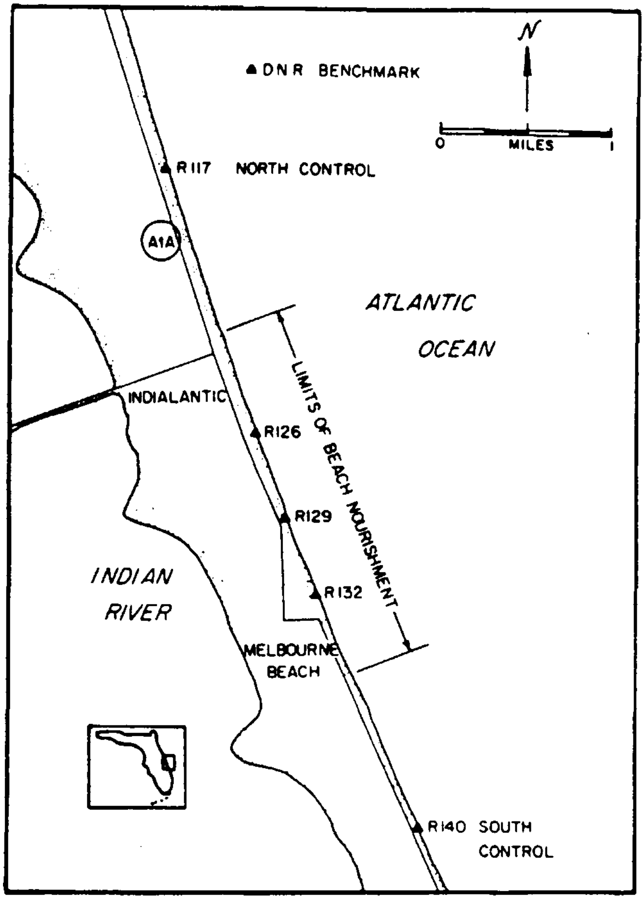

Fig. 1. Location of the sample transects at Indialantic and Melbourne Beach, FL. Transects R126, R129 and R132 were in the beach nourishment area, transect R117 served as the north control, and transect R140 served as the south control. Numbers correspond to Florida Department of Natural Resources coastal construction control line benchmarks.

A total of five transects was established in the study area. All transects were located at fixed points corresponding to Florida Department of Natural Resources coastal construction control line benchmarks. Three transects (R126, R129, R132; Fig. 1) were established within the area of the nourishment project. Two additional transects were established one mile north (R119) and one mile south (R140) of the limits of the beach nourishment area as controls. Each transect was aligned with the corresponding geological benchmark and extended perpendicular to the beach.

Biological samples were taken five times. The first set of samples was taken approximately one week before the project was initiated (October,

1980) and the second set was taken immediately upon completion of the project (February, 1981). Subsequent sampling took place at approximately quarterly intervals (May, July, November; 1981) for a total sampling period following nourishment of one year.

The sampling gear used consisted of a hand-held PVC pipe corer fitted with a 0·5 mm mesh screen at the upper end so that the core could be inverted. A metal cover placed over the open mouth of the core as it was removed from the bottom prevented material from washing out the mouth of the inverted core. Cores taken were 20·22 cm in diameter, 10 cm deep, with a volume of approximately 3243 cm^3.

Sampling was initiated by extending a 121·9 m polypropylene transect rope perpendicular to the beach. The line was marked off at 30·5 m intervals and was secured by a metal stake at the high tide line and by two anchors at the seaward end.

Three replicate core samples were taken at the high tide line (designated 0 m), and at 30·5 m, 61 m, 91·4 m and 121·9 m from high tide along the transect. The latter three sites were sub-tidal at all transects in depths from 1 to 3 m. The 30·5 m sites at all transects correspond to a tidal height of approximately 0·2 m above NGVD (National Geodetic Vertical Datum = Mean Sea Level 1929). The 0 m sites show most variation due to seasonal changes in beach profile and the results of the sand addition to the beaches. Tidal heights were in the approximate range of 1·8 to 3·3 m above NGVD. Stauble *et al.* (1983) provided beach profiles for each sampling date at each sample location.

Samples were sieved in the surf using 0·5 mm Nitex® screens and fixed in a 7% Formalin–seawater solution. Following fixation, samples were re-sieved in the laboratory on a 0·6 mm sieve and the material retained was stained in a rose bengal–ethanol solution. All organisms were then hand sorted from the sediment and preserved in 70% ethanol for later enumeration and identification to the lowest taxonomic level possible.

In the discussion of the results, the term 'transect' refers to the five transect locations along the beach nourishment project (R117, R126, R129, R132, R140). The term 'sites' is used to denote the five sample sites along a given transect (0, 30·5, 61, 91·4, 121·9 m). The term 'dates' refers to the five separate sampling dates.

Statistical analysis of the data consisted of the use of two-way (Model I) analysis of variance (ANOVA) to compare the data among locations and dates. Since it is well known that there are clear differences in faunal composition at different tidal heights (reviewed by McLachlan, 1983), a two-way ANOVA was carried out for each site separately. Two-way ANOVA was carried out for both number of individuals and number of species. Tests of homogeneity of variances (F-max test) indicated some variances to be heterogeneous. All data were square root transformed which removed this heterogeneity.

RESULTS

Community composition

During this study 375 benthic cores were analysed. Total number of individuals for each species at each transect are given in Table 1. The surf zone animal community in this study is species rich (at least 99 taxa), but is dominated in numerical abundance by a few species and taxonomic groups. By far the most numerically dominant group consisted of small individuals, presumably juveniles, of the two coquina clams *Donax parvula* and *Donax variabilis*. Small individuals (<5 mm) of these two species could not be separated during species identification. When this juvenile group is combined with the adults, *Donax* represents 60% of the total individuals collected. Second in overall abundance was the polychaete *Haploscoloplos fragilis* which made up only 7% of total abundance. Two amphipods, *Parahaustorius longimerus* and *Bathyporeia parkeri*, were the third and fourth ranked in terms of total abundance. Other groups were represented by more than 1000 organisms (3% of total abundance) included the polychaete *Paraonis fulgens* and several unseparated species of Turbellaria. The mole crab *Emerita talpoida*, although abundant in a narrow band of the intertidal zone, ranked only 10th and constituted barely 2% of total abundance.

The total numbers of individuals and species found on each sampling date at each transect are shown in Table 2. The five transect locations showed differences in density on any given sampling date, but generally were very similar in the total number of species recorded.

The results of two-way ANOVA for comparing mean numbers of individuals per core across dates and among transects are given in Table 3. At the 0 m site, only the comparison among dates was significant. At the 61 m site, the comparison among transects was not significant, while both the dates and interaction terms were significant. For the other three sites (30·5, 91·4, 121·9 m), the dates, transects and interaction terms were all significant.

The presence of significant interaction terms at four of five sites means that the comparisons of means for the main effects should not be made. To assist in interpretation of the interaction terms, mean number of individuals per core is plotted versus time for each transect at each site in Fig. 2 (Underwood, 1981). Inspection of Fig. 2 can indicate the source of the

TABLE 1
Total Numbers of Individuals for Each Species at Each Transect in the Study Area

Taxon	*Transect*						
	117	*126*	*129*	*132*	*140*	*Total*	*Rank*
CNIDARIA							
unidentified sp.	0	0	1	0	0	1	78
TURBELLARIA							
unidentified spp.	291	77	354	331	13	1 066	6
ANTHOZOA							
Renilla reniformes	1	0	2	0	0	3	58
NEMATODA							
unidentified sp.	7	35	19	13	7	81	21
NEMERTINA							
unidentified spp.	203	224	113	71	107	718	9
CHAETOGNATHA							
unidentified sp.	0	21	4	8	2	35	32
SIPUNCULA							
unidentified sp.	0	1	0	0	0	1	78
ARCHIANNELIDA							
unidentified sp.	38	2	0	39	0	79	23
OLIGOCHAETA							
unidentified spp.	50	10	13	113	15	201	14
POLYCHAETA							
Arabellidae							
unidentified sp.	2	2	2	0	3	9	48
Goniadidae							
Glycinde solitaria	3	4	6	6	4	23	39
Orbiniidae							
Leitoscoloplos fragilis	372	341	507	312	743	2 275	2
Hesionidae							
unidentified sp.	1	0	0	0	0	1	78
Nephytydae							
Intermonephtys sp.	0	0	1	2	1	4	54
Lumbrineridae							
Lumbrineris tetraura	5	6	11	5	6	33	34
Magelonidae							
Magelona papillicornis	106	95	77	70	50	398	11
Nereidae							
Neanthes succinea	3	0	1	0	0	4	54
Onuphidae							
Onuphus eremita	22	33	17	28	57	157	18
Oweniidae							
Owenia sp.	17	11	9	13	16	66	26
Paraonidae							
unidentified sp.	294	322	165	228	261	1 270	5
Sabellaridae							
Phragmatopoma sp.	1	0	2	0	0	3	58
Phyllodocidae							
unidentified sp.	0	0	0	0	2	2	64
Pisionidae							
Pisione sp.	2	0	3	6	1	12	45

TABLE 1—*contd.*

Taxon	*Transect*						
	117	*126*	*129*	*132*	*140*	*Total*	*Rank*
POLYCHAETA							
Spionidae							
Spiophones bombyx	1	0	1	0	0	2	64
unidentified sp.	1	0	0	0	0	1	78
Pectinaridae							
Pectinaria gouldii	1	0	0	0	0	1	78
Syllidae							
unidentified sp.	1	1	0	0	0	2	64
GASTROPODA							
Olivella mutica	15	26	19	14	4	78	24
Polinices duplicatus	0	1	2	0	0	3	58
Terebra cinerea	0	0	0	0	2	2	64
Terebra dislocata	8	7	9	5	14	43	30
BIVALVIA							
Anadara transversa	1	0	0	0	0	1	78
Corbula contracta	0	1	1	0	0	2	64
Crassinella lunulata	0	0	1	0	0	1	78
Crepidula fornicata	0	0	0	0	1	1	78
Donax parvula	90	112	322	178	169	871	7
Donax variabilis	91	71	40	51	65	318	12
Donax juveniles	2574	2827	5070	3962	2802	17235	1
Dosinia elegans	1	0	0	0	0	1	78
Sphenia antillensis	1	0	0	0	0	1	78
Tellina iris	9	15	2	9	24	59	28
COPEPODA							
Cyclopoida							
unidentified sp.	2	8	3	3	2	18	43
Harpacticoida							
unidentified sp.	0	1	2	1	0	4	54
PYCNOGONIDA							
unidentified sp.	1	0	0	0	0	1	78
ISOPODA							
Ancinus depressus	1	0	1	1	2	5	51
Apanthura magnifica	0	3	0	0	0	3	58
Califanthura sp.	0	0	1	0	0	1	78
Chiridotea coeca	10	18	16	29	12	85	20
Exocorallana subtilis	4	2	0	1	5	12	45
Ptilanthura tricarina	0	0	1	0	0	1	78
Tylos latrelli	7	1	0	9	7	24	38
DECAPODA							
Arenaeus cribrarius	0	0	1	0	0	1	78
Emerita talpoida	190	51	61	297	100	699	10
Ogyrides alphaerostris	10	15	17	16	23	81	21
Pagurus longicarpus	1	0	0	0	1	2	64
Pinnixa cristata	0	1	0	0	0	1	78
Lucifer sp.	0	1	1	1	0	3	58
Decapod juveniles	1	8	3	13	3	28	35

(continued)

TABLE 1—*contd.*

Taxon	*Transect*						
	117	*126*	*129*	*132*	*140*	*Total*	*Rank*
CUMACEA							
Cyclaspis varians	11	5	26	11	21	74	25
Oxyurostylis smithi	3	4	5	9	4	25	36
MYSIDACEA							
Bowmaniella sp.	52	34	27	23	28	164	17
Metamysidopsis swifti	74	49	89	50	42	304	13
Mysid juveniles	3	1	1	1	5	11	47
AMPHIPODA							
Acanthohaustorius millsi	17	35	44	41	37	174	16
Ampelisca shellenbergi	1	0	0	0	0	1	78
Atylus urocarinatus	0	3	6	0	11	20	42
Bathyporeia parkeri	410	226	440	325	240	1 641	4
Caprella penantis	5	13	1	0	2	21	40
Corophium sp.	0	0	2	0	0	2	64
Elasmopus pocillimanus	2	2	0	0	1	5	51
Ericthonius brasiliensis	0	1	0	0	0	1	78
Gammarus mucronatus	0	0	0	1	0	1	78
Gammaropsis sp.	0	6	0	0	1	7	50
Gitanopsis tortugae	0	1	0	0	0	1	78
Haustorius canadensis	6	13	13	16	13	61	27
Jassa falcata	0	1	0	0	1	2	64
Letrigonius bengalensis	0	0	0	0	1	1	78
Metharpinia floridana	14	4	12	9	15	54	29
Microprotopus shoemakeri	19	20	124	3	29	195	15
Parahaustorius longimerus	429	436	264	438	293	1 869	3
Parhyale fascigera	0	2	0	0	0	2	64
Parhyale hawaiiensis	0	2	0	0	0	2	64
Parhyalella whelpleyi	0	0	0	0	2	2	64
Eudevenopis honduranus	161	160	155	94	272	842	8
Podocerus brasiliensis	1	3	0	0	1	5	51
Pontogeneia longleyi	0	1	1	0	6	8	49
Protohaustorius deichmannae	13	9	9	6	4	41	31
Protohaustorius wigleyi	2	5	2	7	0	16	44
Rhepoxynius epistomus	30	31	19	38	27	145	19
Stenothoe sp.	2	1	0	0	0	3	58
Synchelidium americanum	3	6	8	3	1	21	40
Tabatzius muelleri	0	1	0	0	0	1	78
ECHINODERMATA							
Mellita sp.	6	9	4	6	0	25	36
Holothuroidea juveniles	0	1	0	0	1	2	65
Ophiuroidea juveniles	2	2	0	0	0	4	54
CHORDATA							
Branchiostoma sp.	6	6	10	7	5	34	33
Symphurus pelicanus	0	1	0	0	0	1	78

TABLE 2
Total Numbers of Individuals and Species for Each Transect in the Study Area. (Asterisks indicate control transects)

Transect	*Sampling period*									
	10/80		*02/81*		*05/81*		*07/81*		*11/81*	
	indiv.	*spp.*	*indiv.*	*spp.*	*indiv.*	*spp.*	*indiv.*	*spp.*	*indiv.*	*spp.*
117*	1 805	32	843	30	1 061	40	1 550	40	401	26
126	1 078	24	371	27	1 317	40	1 600	33	921	45
129	2 349	29	607	31	1 373	37	3 394	48	840	20
132	2 033	29	422	18	1 384	37	2 187	39	905	28
140*	1 130	31	379	19	2 398	40	891	38	886	29

Total number of taxa at all transects –99.
Total number of individuals at all transects—32 125.

TABLE 3
Results of Two-way Analysis of Variance for Number of Individuals for Each Sample Site Considered Separately. All data were square root transformed. (n.s. = not significant)

Site	*Factor*	*F ratio*	*Significance*
0 m			
	Dates	5·39	$p < 0{\cdot}01$
	Transects	1·47	n.s.
	Interaction	1·73	n.s.
30·5 m			
	Dates	22·19	$p < 0{\cdot}001$
	Transects	2·61	$p < 0{\cdot}050$
	Interaction	4·54	$p < 0{\cdot}001$
61 m			
	Dates	22·21	$p < 0{\cdot}001$
	Transects	2·10	n.s.
	Interaction	3·65	$p < 0{\cdot}001$
91·4 m			
	Dates	39·19	$p < 0{\cdot}001$
	Transects	7·53	$p < 0{\cdot}001$
	Interaction	2·64	$p < 0{\cdot}01$
121·9 m			
	Dates	25·85	$p < 0{\cdot}001$
	Transects	3·29	$p < 0{\cdot}05$
	Interaction	2·76	$p < 0{\cdot}01$

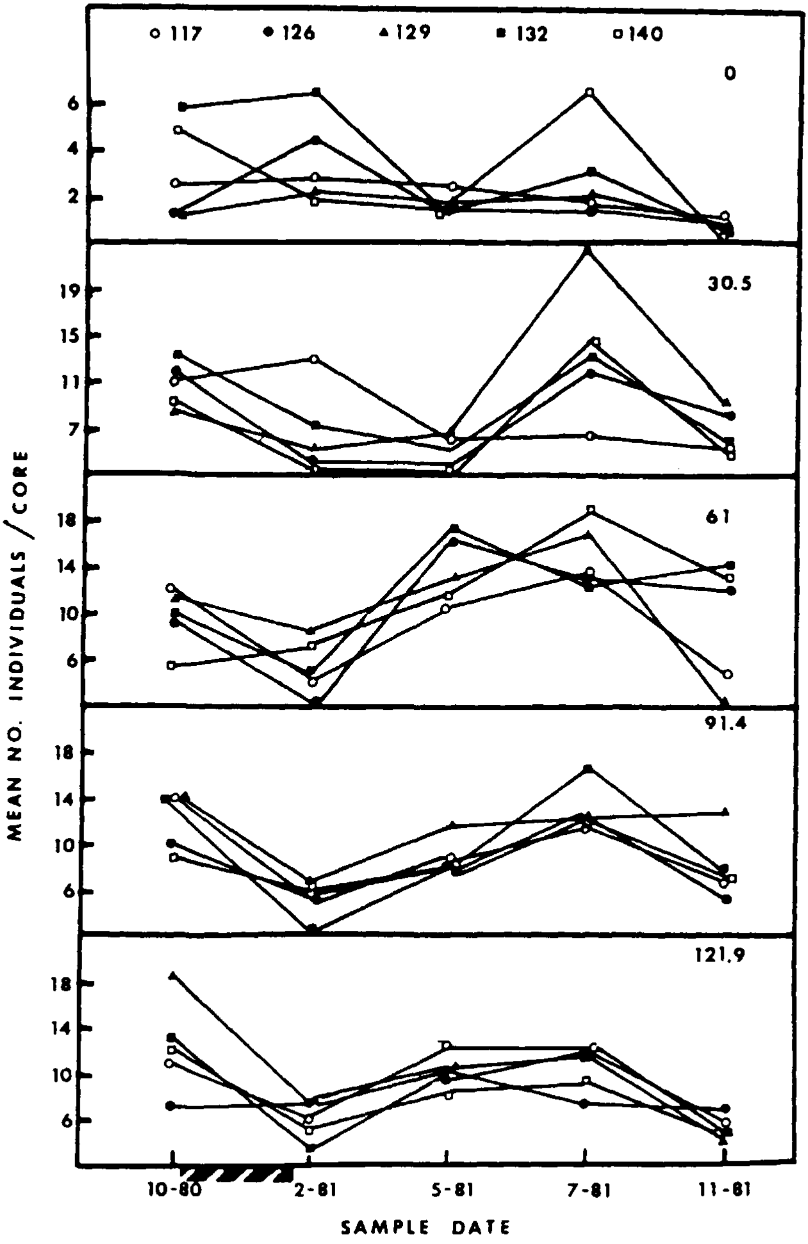

Fig. 2. Comparison of mean number of individuals per core for each transect over the period of the study. Data for each site are presented separately to assist in interpretation of the significant interaction terms from analysis of variance (Table 3). The broken line indicates the period of beach nourishment. All data are square root transformed values.

significant interaction term. At the 30·5 m site, north control transect 117 shows an increase in abundance in February while the other four transects show a decrease, while in July, 117 shows no increase as compared with increases at the other four transects. Similarly, at the 61 m site, south control transect 140 shows an increase in February while the other four transects show decreases. Again in July, two transects (126, 132) show decreases while the other three (117, 129, 140) show increases.

At 91·4 m, all transects show decreases following nourishment, while in the July sample, transect 132 shows a greater increase than other transects. In the final sample at this site, transect 129 increases slightly while the other four transects decrease.

For site 121·9 m, transect 126 shows a slight increase in the February sample while the other four transects show decreases. Again in July and November, the direction of change for transect 126 is opposite that for the other four transects.

Based on Fig. 2, the significant interactions between data and transect do not appear to be indicative of significant negative effects of beach nourishment. As indicated above, a difference in the direction of change in abundance of a single transect at a single date appears to have been sufficient to generate the significant interaction term. At the offshore sites (61, 91·4, 121·9 m), there was no indication that the group of nourishment transects possessed lower abundances on any sampling data than did the group of control transects (Fig. 2). Only at the 30·5 m site immediately after dredging was abundance at one control transect (117) significantly greater than the three nourishment transects (Student–Newman–Keuls test, $p < 0.05$). Whether this difference is actually related to nourishment is unclear since, by the following May, the opposite relationship had occurred (Fig. 2).

The results of two-way ANOVAs comparing the mean number of species per core across dates and among transects are given in Table 4. The comparison among transects was not significant at any site. The comparison among dates was significant for the 0 m and 30·5 m sites. Both the comparison among dates and the interaction term were significant at the 61, 91·4 and 121·9 m sites.

The interpretation of the interaction terms is indicated by Fig. 3. At the 61 m site, one of the nourishment transects (129) showed an increase in mean number of species in February, while the other four transects showed decreases. At the same site, transect (126) showed a decrease in the May samples while the other transects either showed little change (129) or increases (117, 132, 140). For the 91·4 and 121·9 m sites, transects showed opposite directions of change in the mean number of species during all sample dates. None of the patterns of change in number of species shown in Fig. 3 are consistent with the change having resulted from a negative effect

TABLE 4

Results of Two-way Analysis of Variance for Number of Species for Each Sample Site Considered Separately. All data were square root transformed. (n.s. = not significant)

Site	*Factor*	*F ratio*	*Significance*
0 m			
	Dates	11·17	$p < 0{\cdot}001$
	Transects	0·40	n.s.
	Interaction	1·23	n.s.
30·5 m			
	Dates	15·43	$p < 0{\cdot}001$
	Transects	0·73	n.s.
	Interaction	1·83	n.s.
61 m			
	Dates	11·50	$p < 0{\cdot}001$
	Transects	1·13	n.s.
	Interaction	3·49	$p < 0{\cdot}001$
91·4 m			
	Dates	16·54	$p < 0{\cdot}001$
	Transects	1·74	n.s.
	Interaction	3·33	$p < 0{\cdot}01$
121·9 m			
	Dates	23·47	$p < 0{\cdot}001$
	Transects	1·19	n.s.
	Interaction	2·16	$p < 0{\cdot}050$

of beach nourishment. Fig. 3 shows the mean number of species for control and nourishment transects to be interspersed in their ranks at all sites.

The presence of a significant seasonal component of density variation was indicated at the 0 m site (Table 3, Fig. 2). Figure 2 suggests that there is a similar seasonal component at the remaining sites as well, despite the significant interaction term (Table 3). Abundances on most transects at these sites showed the same general pattern of decrease in the winter, increases in late spring and summer, and decreases again in the fall. These changes are visually deemphasized in Fig. 2 due to the square root transformation of the data.

Similarly, there was a significant seasonal component of variation in number of species at the 0 and 30·5 m sites (Table 4, Fig. 3). Seasonal changes at the other sites are suggested by the highly significant F values (Table 4), but are not clearly shown in Fig. 3. The pattern of seasonality is more clearly shown for both density and number of species in Fig. 4, which compares untransformed data for the nourishment and control locations

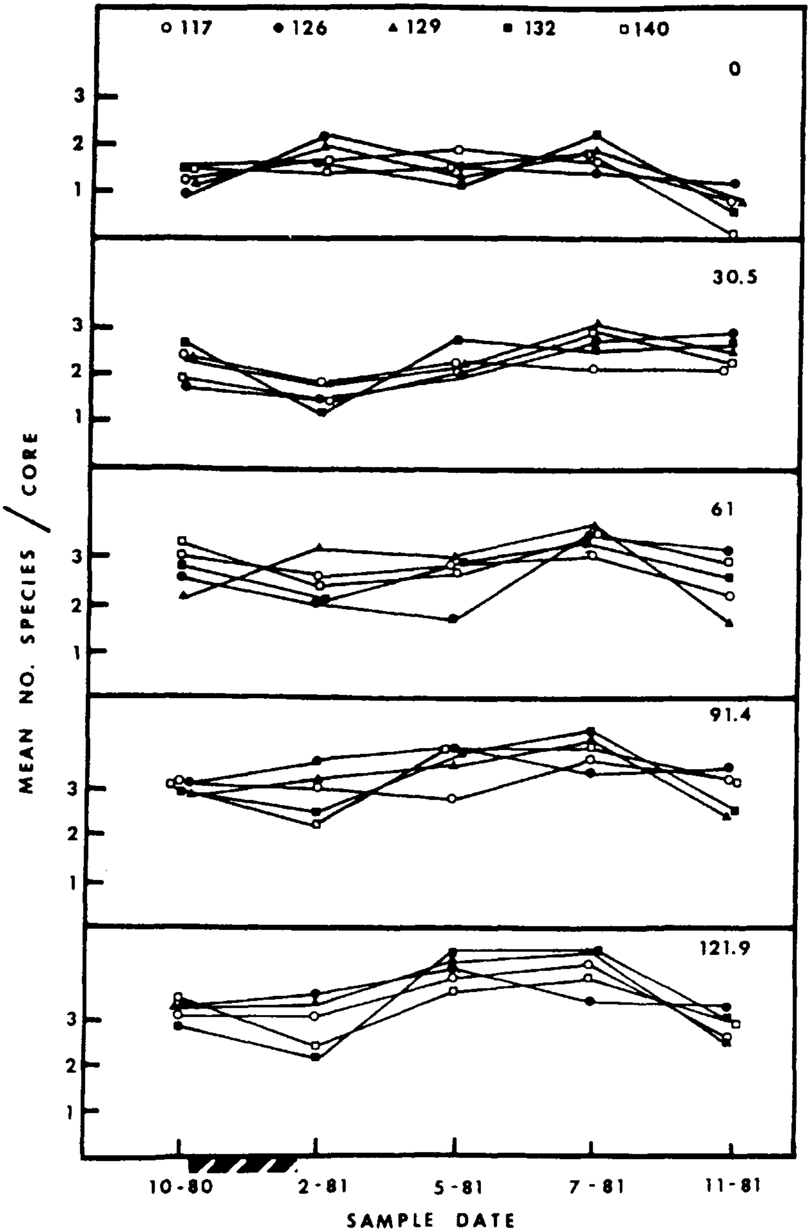

Fig. 3. Comparison of mean number of species per core for each transect over the period of the study. Data for each site are presented separately to assist in interpretation of the significant interaction terms from analysis of variance (Table 4). The broken line indicates the period of beach nourishment. All data are square root transformed values.

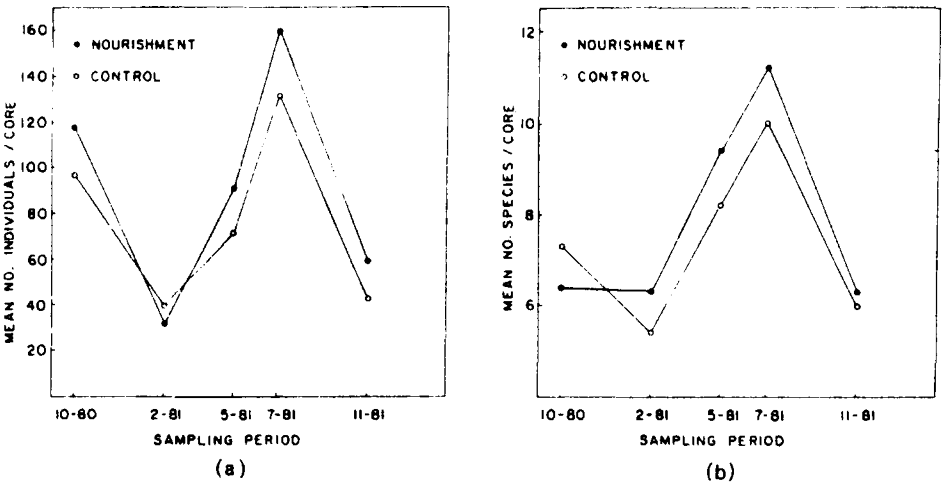

Fig. 4. Comparisons of (*a*) mean number of individuals and (*b*) mean number of species per core between nourishment locations and control locations for samples pooled across all sites during the study period.

for samples pooled across all sites. Density and number of species were lowest in the winter, increased to a summer maximum and decreased again in the fall samples. Both nourishment area and control area samples showed qualitatively similar patterns.

Figure 5 shows the comparison of mean total number of individuals per core versus site for both the nourishment and control sampling locations

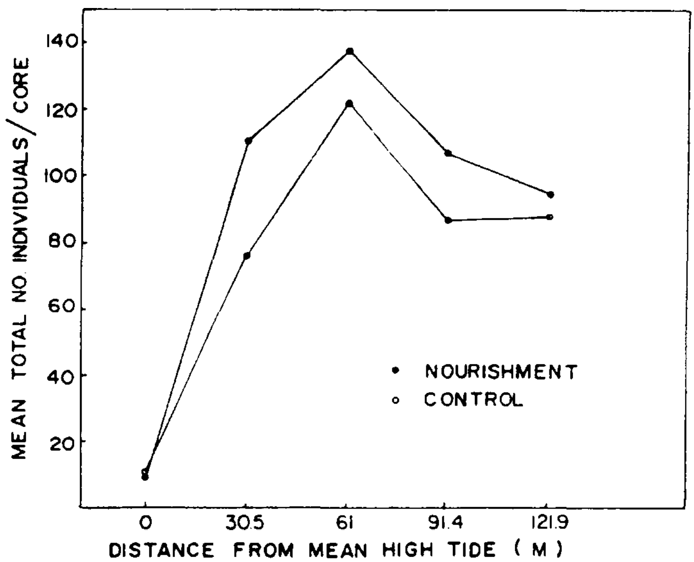

Fig. 5. Comparison of mean total number of individuals per core between nourishment and control locations at sites from high tide to 121·9 m.

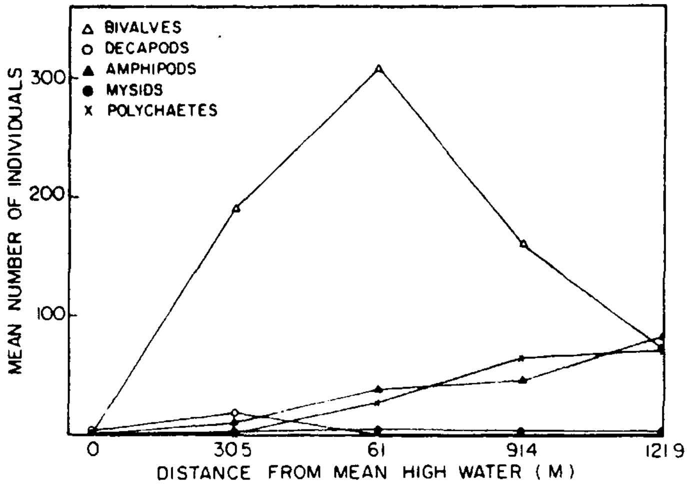

Fig. 6. Comparison of mean number of individuals per core at sites from high tide to 121·9 m among five major taxonomic groupings.

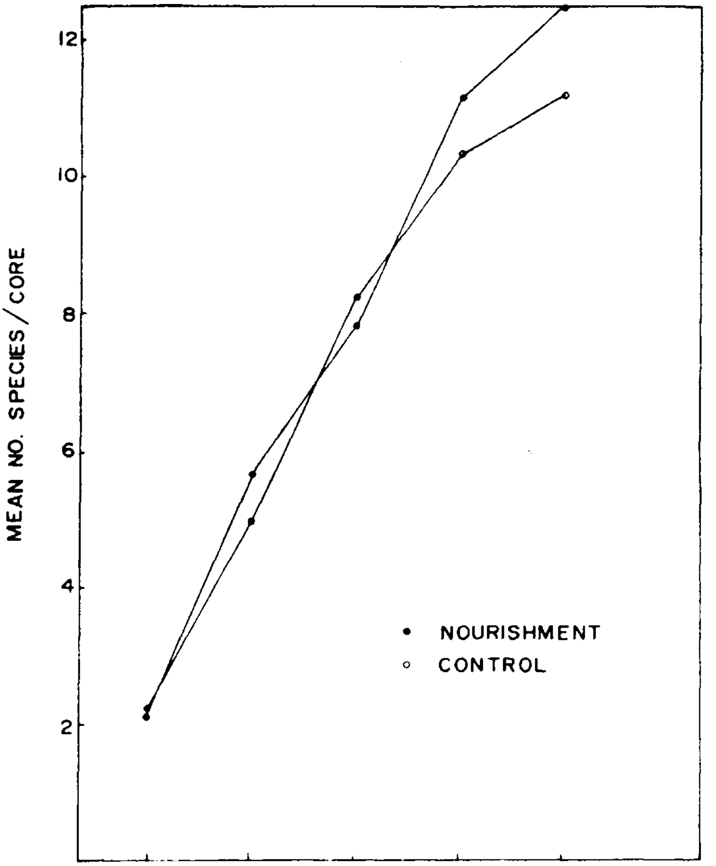

Fig. 7. Comparison of mean number of species per core between nourishment and control locations at sites from high tide to 121·9 m.

(samples pooled across all dates). Both groups of locations show large increases in density with distance from shore with a peak in average organism density at the 61 m site. A breakdown of mean number of individuals per core versus distance from shore into various major taxonomic groupings indicates that the peak in density at 61 m from the high tide line is almost entirely due to the bivalves (Fig. 6). The largest component of the bivalve abundance at this site was composed of juveniles of the two *Donax* species. Figure 7 indicates that there was a steady increase in number of species found with increasing distance from the high tide line.

DISCUSSION

The data collected in this study show little evidence that the nourishment of beaches in Indialantic and Melbourne Beach, Florida, had any significant negative impact on the benthic fauna of the near-shore zone. Comparisons of locations receiving nourishment sand with those serving as controls rarely showed any significant difference between these two treatments, either for the total abundance or total number of species present.

Factors relating to the distance from the high tide line appear to have a much stronger effect on average abundance and number of species than did the process of beach nourishment. The steady trend of increasing number of species with increasing distance from shore was unaffected by beach nourishment. Similarly, the pattern shown for abundance, which showed a peak at the 61 m site, was not altered by beach nourishment.

Seasonal patterns of mean number of individuals and number of species showed virtually identical patterns for both nourishment and control locations. The pattern of a winter minimum and a summer maximum in abundance is typical for organisms in the surf-zone habitat of the southeast coast of the US (Spring, 1981; Matta, 1977; Reilly & Bellis, 1983; Leber, 1982b).

The possibility should be considered that the lack of differences observed between control and nourishment locations might be due to the controls having been similarly affected by the nourishment activities. Beach profile sampling (Stauble *et al.*, 1983) revealed that substantial quantities of nourishment sand were moved into the south control site (R140) during the year following beach nourishment. No evidence of any movement of nourishment sand into the north control site (R117) was seen at any time. However, comparisons of the single north control with the other four transects (Figs 2, 3) do not show any consistent pattern of decreases at the nourishment locations and south control versus the north control location.

The lack of detectable, negative effects of beach nourishment on the benthic fauna in this study may be due to several factors. Previous work at

Melbourne Beach (Spring, 1981) indicates that the dominant *Donax* species tend to move offshore in the winter and thus would tend to be located beyond the zone receiving sand. Leber (1982a) has also indicated that *Donax parvula* moves away from the beach in the fall although, at the site in North Carolina studied by Leber, *Donax variablis* did not do so. Geological data (Stauble *et al.*, 1983) collected during the same time frame as the present biological study, showed that there was little shift in mean grain size or sediment sorting at the offshore (61 to 121·9 m) sample sites. Since mean grain size and sorting of nourishment sand differed from native sand (Stabule *et al.*, 1983), this suggests that significant quantities of nourishment sand were not moving into the offshore region. The offshore sites tend to have higher abundances and species diversity than the inshore sites so that the bulk of the animals in the near-shore zone would be largely unaffected by nourishment sand. Such offshore gradients in abundance and diversity are typical of surf zone areas (Spring, 1981; Matta, 1977; Salomon, 1975).

Another factor minimizing nourishment impact may have been the nature of the sand added to the system. The mean grain size of the nourishment sand was somewhat coarser (1·31 diameter vs. 1·7 diameter, Stauble *et al.*, 1983) than the ambient mean grain size. The nourishment sand was also more poorly sorted (Stauble *et al.*, 1983). There was a very rapid loss of fine material and complete readjustment of sediment characteristics of the foreshore occurred in 9 months (Stauble *et al.*, 1983). Since the nourishment material was trucked in from an on-land spoil pile, it is likely that levels of possibly toxic hydrogen sulfide in the sand were low. Because the *Donax* had moved offshore in winter, the primary macrofaunal species remaining at the inshore (30·5 m) site would be the mole crab *Emerita talpoida*. Hayden & Dolan (1974) have shown that in a case of beach nourishment where sand came from an on-land spoil site and sediment mean grain size was a reasonable match to ambient grain size, *E. talpoida* was little affected by beach nourishment although the project consisted of nearly 1 million m^3 of fill sand. Hayden & Dolan (1974) indicated that the lack of mortality was because this species is very mobile and the animals simply moved away from the area of immediate disturbance and rapidly returned after the actual sediment deposition had ceased in a local area. In contrast, in a beach nourishment project where the nourishment sand was pumped directly from an estuarine area and contained large amounts of clay materials and hydrogen sulfide, *Emerita* as well as *Donax* and other animals disappeared from the beach (Reilly & Bellis, 1983). Loss of organisms occurred both onshore and possibly offshore as well, since adults failed to move onshore in the spring (Reilly & Bellis, 1983). Additionally, pelagic larval recruitment was inhibited and initial colonization by *E. talpoida* on the nourished beach was delayed by one month. The comparison of these results with those described by Hayden & Dolan (1974) and those found in the present study suggested that poor grain size match and possibly hydrogen sulfide release may be factors of importance in determining the impact of a given beach nourishment project on the benthic fauna.

ACKNOWLEDGEMENTS

We thank Drs D. Stauble and T. Roberts for their assistance with the initiation of this project and, together with R. Johnson, for their assistance with the field collections. K. Cairns, P. Mikkelson and M. A. Capone provided considerable taxonomic assistance. M. A. Nelson, K. Petruszka and J. Prappas assisted with the figures.

This work was funded by the US Army Corps of Engineers, Jacksonville District, Grant No. DACW17-80-C-0069. Additional support for the authors while completing this work was provided by the Florida Sea Grant College Program with support from the National Oceanic and Atmospheric Administration, Office of Sea Grant, US Department of Commerce, Grant No. NA80AA-0-00036, and by Mote Marine Laboratory.

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